Progress Report
(August 2002-March 2003)

by

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on the project

Seasonal Atmospheric Predictability Assessment and the Role of Oceans

1. Project Goals

The primary goal of this project is to determine the seasonal predictability of the atmosphere, focusing on the oceanic origins for such predictability. The assessment involves analysis of the simulation skill of the NSIPP climate model, comparing its skill to that of other models and also other methods (e.g., empirical) for seasonal predictions. The focus includes the role of El Niño/Southern Oscillation (ENSO) in predictability, and also the predictability that may be related to other, non-ENSO sources of oceanic variability. Our long term goal is to determine these various oceanic sources of climate predictability, and assess the extent to which they themselves can be forecast. In this regard, the project also will develop experimental seasonal prediction tools that can be used to evaluate and establish benchmarks for the routine NSIPP climate predictions derived from coupled models.

2. Progress and Illustrations of Preliminary Results

Our initial efforts involved acquiring and combining two sets of exisiting NSIPP climate simulations, one being a 9-member ensemble for 1930-1999 performed at 2 x 2.5 degree resolution, and a second being the so-called Climate of the Twentieth Century runs consisting of a 14-member ensemble for 1901-1999 of the same model, but using coarser horizontal resolution. The data were made conveniently available to us by NSIPP scientists through a web server (http://nsipp.gsfc.nasa.gov/data_req/atmos), from which the history files of the NSIPP model's monthly statisitics were retrieved.

These two model data sets were found to possess very similar interannual variations, justifying their combination into a single, 23-member ensemble NSIPP data set spanning

1930-99. This data is the basis for our on-going assessment of atmospheric sensitivity to oceanic forcing and predictability, some results from which are highlighted below.

i) Response to ENSO

The NSIPP ensemble is found to exhibit a realistic response to ENSO. This is true of many other climate models also, but our analysis suggests that the NSIPP model also reproduces some important higher-order sensitivities including the asymmetry of extratropical response to warm versus cold phases of ENSO.

Shown in Fig. 1 is an observational analysis, using the NCEP/NCAR reanalysis 500-mb height data spanning 1948-2003, of the January-February-March seasonal height response to warm events (top, left), cold events (top right), the linear ENSO signal (bottom, left), and the nonlinear ENSO signal (bottom, right). An open question continues to be whether the appreciable asymmetry in the spatial expression of the wintertime height anomalies that contrasts El Niño and La Niña events is a true measure of the atmosphere's sensitivity to details of the tropical SST forcing, or merely a sampling artifact. Afterall, though the linear signal can be reliably detected from the 56 years of observational data entering the analysis of Fig. 1, the higher order statistics of ENSO impacts are arguably less detectable.

Figure 2 shows the same analysis, but performed using the NSIPP 23-member ensemble data. The agreement with observations both of the linear signal and the nonlinear signal is readily apparent. The results confirm the realism of the sensitivity of the NASA climate model to the leading source of potential predicability, namely ENSO. They also provide the best evidence to date that the higher order sensitivity to ENSO's opposite phases witnessed in nature is indeed a measure of sensitivity rather than a data problem. Further analysis of the causes for such sensitivity is thus warranted using the volume of NSIPP model data.

ii) Simulation skill

The simulation skill of the NSIPP 23-member ensemble has been calculated for the seasonally averaged 500-mb height anomalies over the Pacific-North American (PNA) region. The metric we use is the anomaly correlation skill score averaged over the domain 20N-70N, 180-60W. We have compared the skill of the NSIPP model to two other tools for seasonal predictions. One is a multi-GCM ensemble of models that includes the NCAR-CCM3, GFDL-R30, ECHAM3, and NCEP-MRF9 models. The total ensemble size of that tool is 46-members, and those spectral models were run at similar spatial resolution to the grid-point NSIPP model. The other tool is a linear multi-variate model based on CCA that relates the seasonal variability of observed tropical SST fields to the seasonal variability of observed 500-mb heights over the PNA region. The CCA model has been trained with 30-years of independent data, and the skill was assesed for the independent 1980-99 verification period. Figure 3 compares the correlaton skill of these three data sets for each of the 12 overlapping seasons during the year. The dynamical models are consistently more skillful than the empirical tool, and the NSIPP ensemble is as skillful as the multi-GCM ensemble.

A more detailed analysis of skill for each of the winter seasons during 1980-99 is provided in Fig 4. The reasons for the exceedence of skill of the dynamical tools relative to the empirical tool are under investigation, and that analysis is expected to clarify the prospects for seasonal predictability of climate, and its oceanic origins. Suffice it to say here that some of the exceedence in skill is related to the use of large ensembles, together with the fact that the dynamical models have realistic sensitivity to the observed interannual variations of sea surface temperaures. The observational record is undoubtedly too brief to extract the various sensitivity patterns beyond those most immeditately related to ENSO, and we wish to determine the nature of those patterns using the GCM data.

iii) Climate trends since 1950

An important, and unsolved problem is the origin for the large trends in extratropical climate since about 1950. Figure 5 shows the 1950-99 linear trend in 500-mb heights and tropical sea surface temperatures (SSTs) during winter. The key features are trends toward positive phases of both a PNA-like pattern and the North Atlantic Oscillation (NAO) pattern. These trends in flow regimes have been at the heart of regional trends in surface temperature and rainfall in recent decades occurring over the Northern Hemisphere What is the attribution for these changes? Are they mere sampling fluctuations of a noisy atmospheric system, and to what degree are they coupled to slow changes in other components of the climate system? One specific problem that the project is addressing is the extent to which the climate trends in circulation patterns can be understood as the remote response to the trend toward warmer tropical SSTs.

That the observed trends are not merely random sampling fluctuations of the atmosphere is confirmed by the analysis of the 1950-99 trend in 500-mb heights taken from the NSIPP 23-member ensemble average (Fig. 6, left panels). There is in fact a striking similarity in the spatial patterns of simulated and observed trend paterns over the Northern Hemisphere. The simulated trend is weaker by about a factor of 2, but it should be noted that some individual members of the NSIPP suite have trend amplitudes comparable to those observed, and the observed trend should best be viewed as but one sample of a distribution of possible outcomes given the climate forcings of the last half century.

But which climate forcings have been relevant? The NSIPP runs have not been subjected to the temporal variations in the atmosphere's chemistry (except to the extent that those have imparted a print onto the global SSTs), and that might be one important factor explaining the differences in amplitudes between observed and modeled trends. The NSIPP experiments do confirm, however, that the observed trend pattern is entirely consistent with the recent history of SST variations, and the challenge is to determine which ones are responsible. In our prelimiinary analysis on that question, another multi-variate statistical model has been developed that relates patterns of monthly tropical rainfall variability to 500-mb height variations. We have been especially interested to understand extratropical climate sensitivity to the positive rainfall trends over the Indian ocean simulated in the NSIPP runs (Fig. 6, lower left), a behavior consistent with the underlying warming of the Indian ocean itself (see Fig. 5, bottom). The analysis, shown on the right side of Fig. 6, suggests that a positive NAO response may indeed be a pattern of sensitivity to enhanced Indian ocean rainfall, and that the trend in North Atlantic climate of recent decades may itself be a forced response to sea surface warming over the Indian ocean. The analysis however offers little guidance on the cause for the Pacific-North American climate change, which is evidently not related to the Indian ocean warming. More analysis on this matter will be pursued through new, coordinated GCM simulations as described further below.

(iv) Coordinated atmospheric GCM experiments

The PI's have begun coordinating designed atmospheric GCM experiments to address the role of the Indian ocean in climate variability on the one hand, and the role of the recent multi-decadal warming trend of the tropical oceans as a whole in regional climate change on the other hand. The experiments involve the NCEP-GFS, the NCAR-CCM3, and the NSIPP-1 model (in collaboration with S. Schubert and M. Suarez), each forced with identical idealized tropical SST anomalies. Large ensembles will again be generated to ensure unbiased detection of the ocean's role. The multi-model approach (rather than just using the NSIPP model, for example) is warranted for assesing robustness since there is little observational constraint upon which to judge the realism of any single model for the questions being asked.

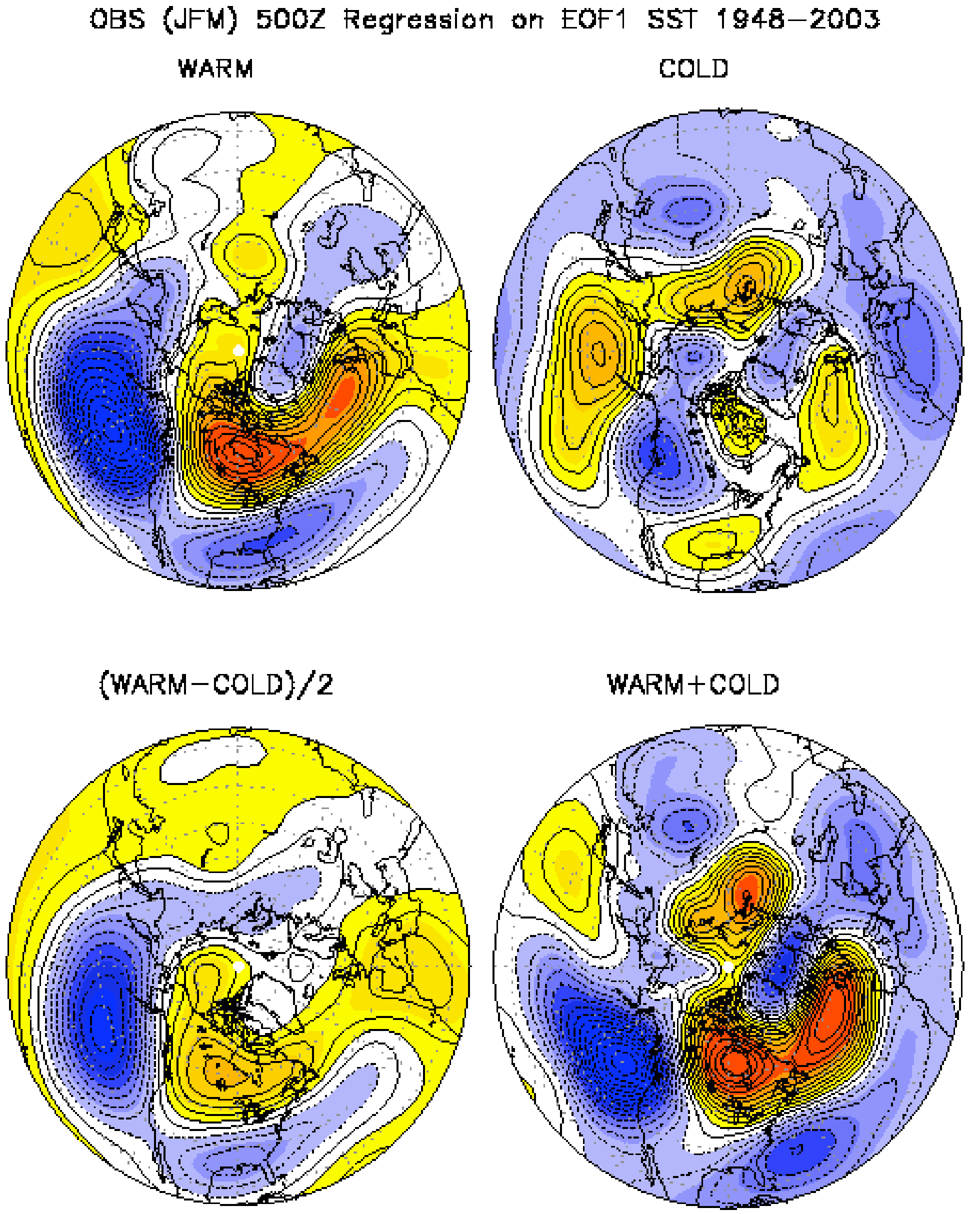

Figure 1. Observed wintertime 500-mb height anomalies associated with warm (El Niño) events, cold (La Niña) events, the linear (warm-cold) ENSO signal, and the nonlinear (warm+cold) ENSO signal. Positive (negative) anomalies in solid (dashed) contours every 5 meters

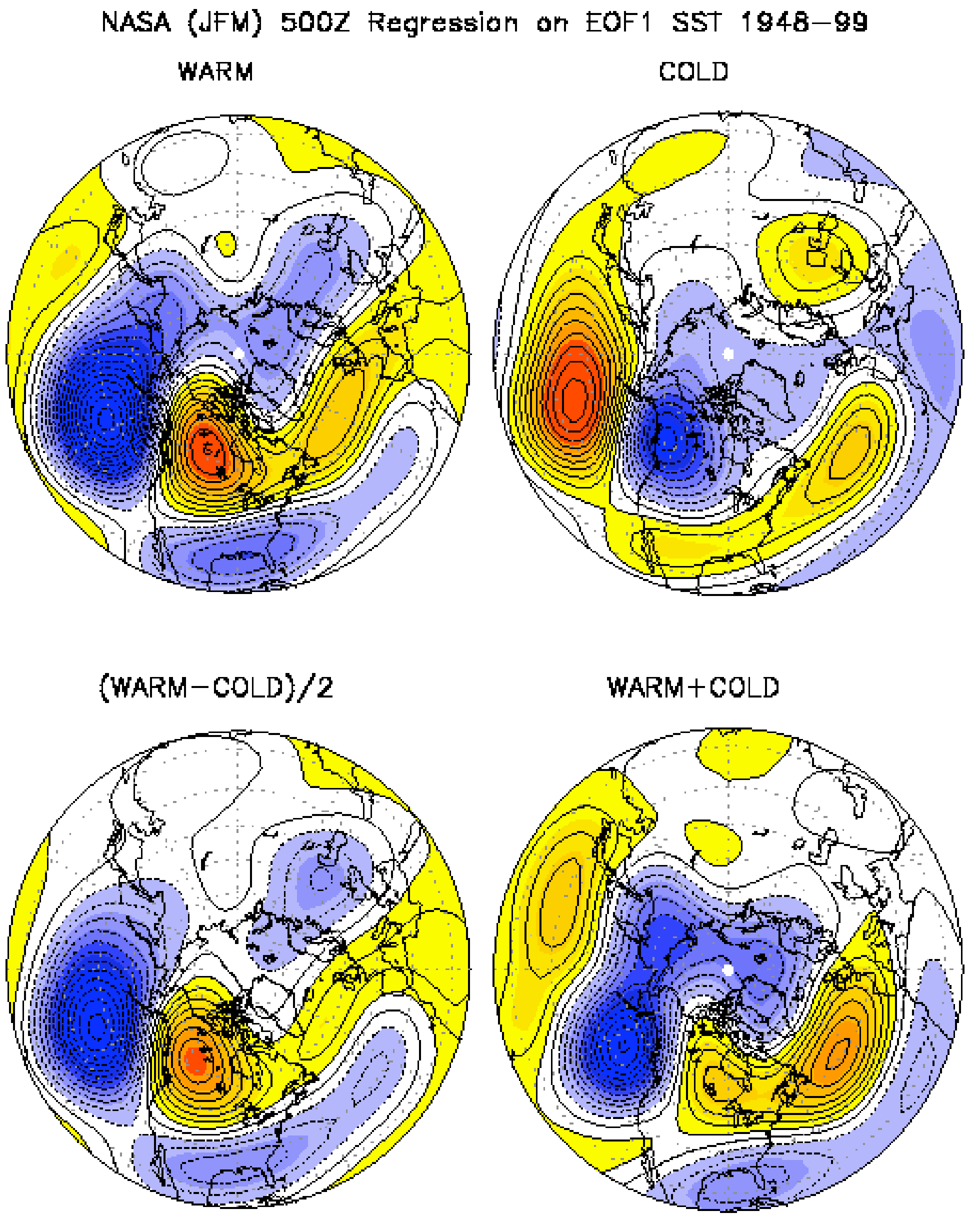

Figure 2. NSIPP simulated wintertime 500-mb height responses to warm (El Niño) events, cold (La Niña) events, the linear (warm-cold) signal, and the nonlinear (warm+cold) signal. Positive (negative) anomalies in solid (dashed) contours every 5 meters.

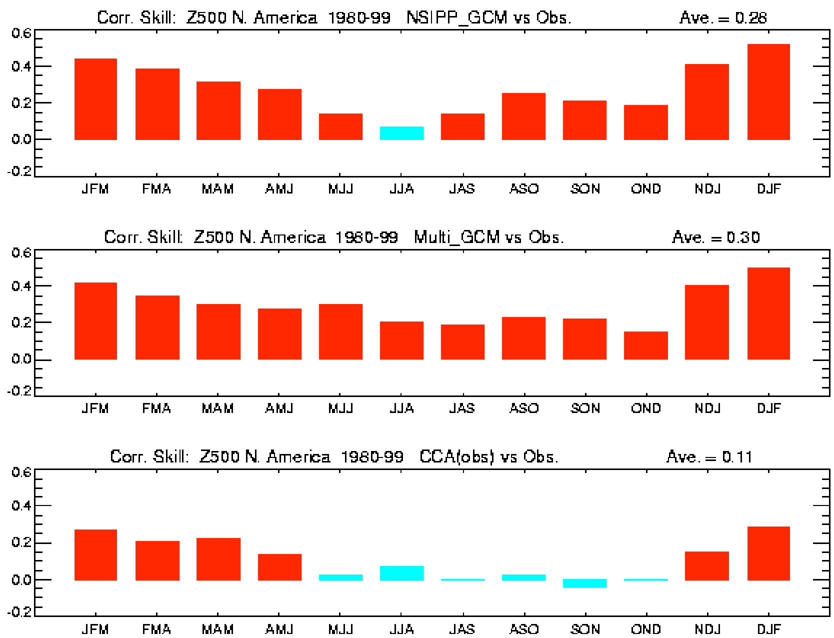

Figure 3. The seasonal cycle of correlaton skill of PNA-sector 500-mb heights basedon the NSIPP ensemble (top), the multi-GCM ensemble based on CCM3, GFDL, ECHAM3, and MRF models (middle), and an empirical CCA model trained on the observed tropical SST-500-mb height relations in the historical record (bottom). For each season, the skill is the average of the 20-seasons during 1980-99, a verification period that is independent from the training of the CCA.

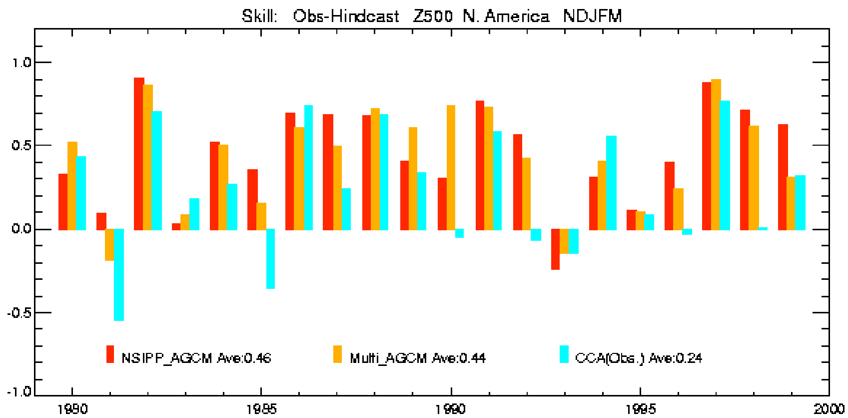

Figure 4. Anomaly correlaton skill scores for PNA-sector 500-mb heights averaged for the seasons NDJ, DJF, and JFM for each year during 1980-99. First bar is based on NSIPP 23-member ensemble, second bar is based on a independent 46-member multi-GCM ensemble, and third bar is based on an observational trained CCA model relating tropical SST to PNA sector 500-mb height for independent 30-year training periods.

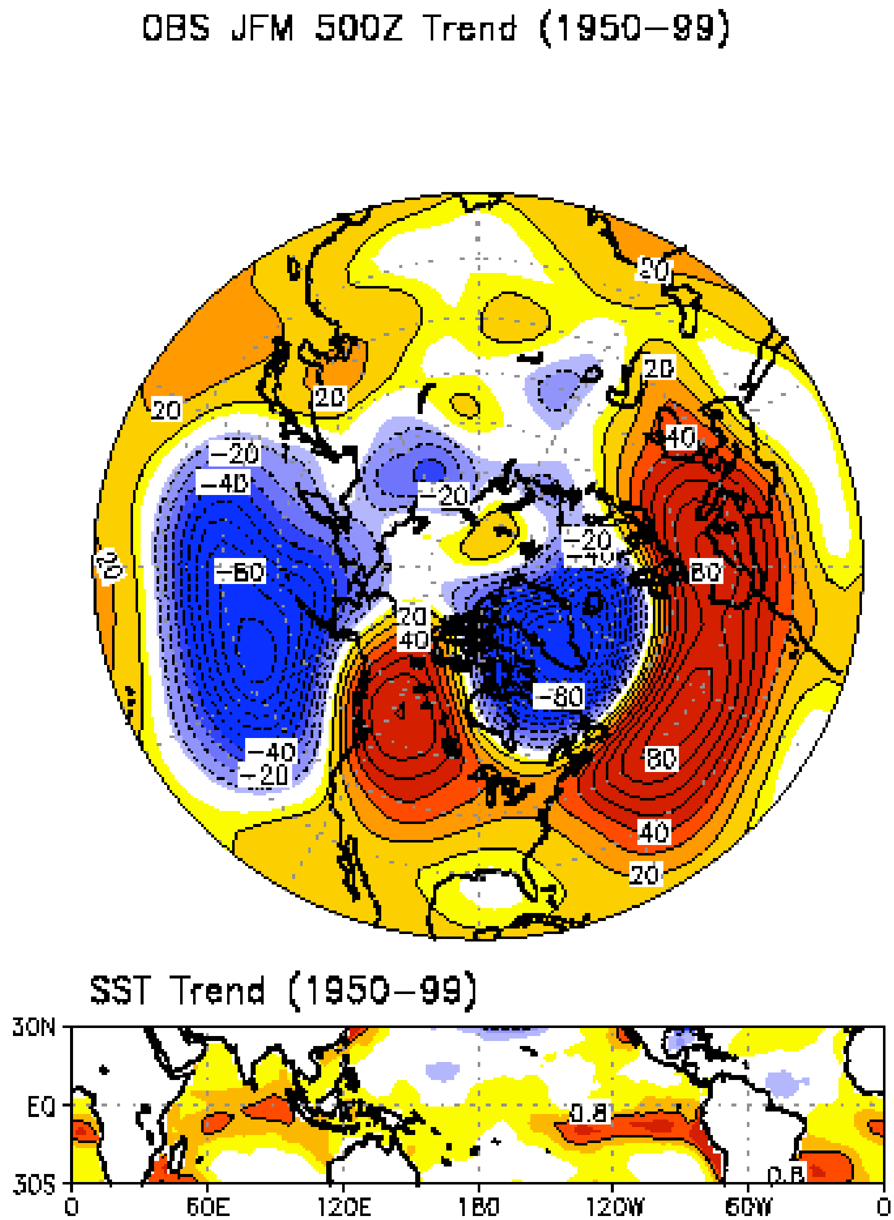

Figure 5. The observed linear trend in JFM 500-mb heights (top) and tropical sea surface temperatures (SSTs) (bottom) during 1950-99. Amplitudes are the change/50 years as calculated by multipling the slope of the trend at each point by 50.

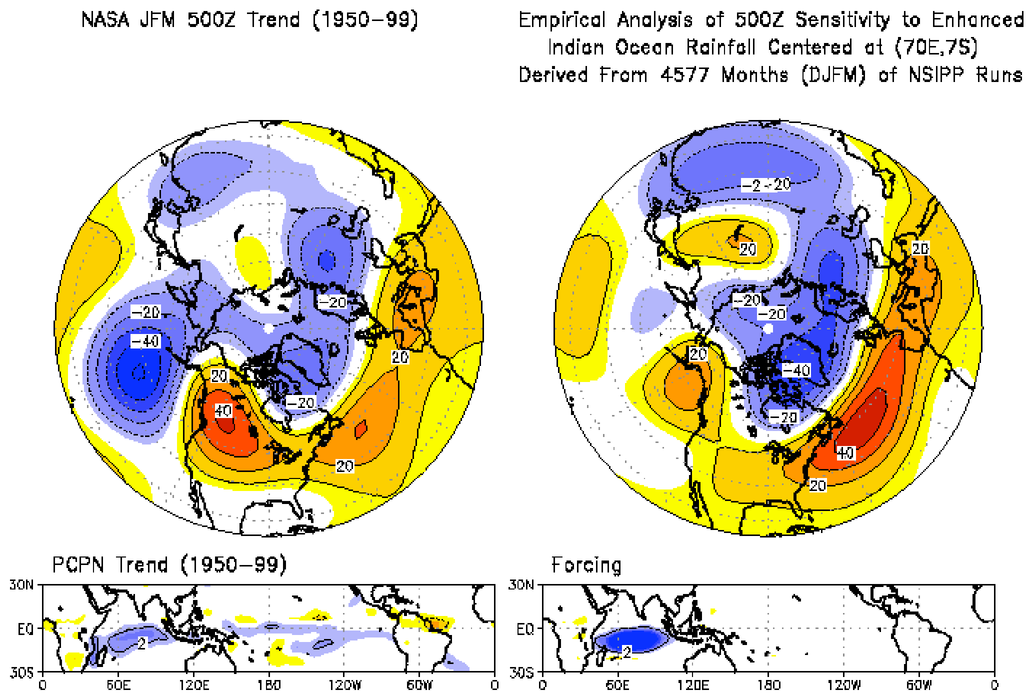

Figure 6. The NSIPP 23-member ensemble linear trend in JFM 500-mb heights (top, left) and tropical rainfall (bottom, left) during 1950-99. Amplitudes are the change/50 years as calculated by multiplying the slope of the trend at each point by 50. An empirical analysis of the NSIPP model's wintertime 500-mb height sensitivity (top, right) to increased Indian Ocean rainfall (bottom, right).